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First photographic record of marbled cat *Pardofelis marmorata* Martin, 1837 (Mammalia, Carnivora, Felidae) in Nepal

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Abstract

The marbled cat *Pardofelis marmorata* is a Near Threatened small felid. The cat's presence in Nepal is based on an anecdote. A camera trap-based study to access diversity and abundance of terrestrial mammals in eastern Nepal accumulated 3,014 camera trap days and resulted in 5,176 photographs of 17 medium-large sized mammal species. Amongst them, a marbled cat was captured at a single camera trap station in January 2018. The camera trap-capturing the marbled cat was located in the secondary forest at an altitude of 2,750 m a.s.l., dominated by free-ranging cattle close to a permanent human settlement (1.4 km) and a temporary cattle herding camp (0.4 km). This is the first photographic evidence of a marbled cat in Nepal. In this survey, we also recorded three other felid species: common leopard *Panthera pardus*, Asiatic golden-cat *Catopuma temminckii* and leopard cat *Prionailurus bengalensis.* We recommend detailed year-round camera trap surveys in the mid-hills of eastern Nepal along with research on adaptation of the small

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felids to human-dominated areas and assessment of immediate threats for preparing sound conservation management plans of the marbled cat and its sympatric species. Initiation of conservation programmes engaging local *dokpa* (herders) is necessary.

Keywords
Marbled cat, *Pardofelis marmorata*, trail camera, small cats, Eastern Himalayas, Nepal

Introduction

The marbled cat, *Pardofelis marmorata* Martin, 1837, is categorised as 'Near Threatened' in the IUCN Red List of Threatened Species (Ross et al. 2016) and nationally data deficient in Nepal (Amin et al. 2018; Jnawali et al. 2011). The marbled cat, listed in CITES Appendix I is a member of the Felidae family along with 14 genera and 42 species of cats (ITIS 2018). This small wild cat is a member of the bay cat lineage along with the Asiatic golden cat *Catopuma temminckii* and bay cat *Catopuma badia.* The marbled cat is similar in colouring to the clouded leopard *Neofelis nebulosa,* with dark blotches, stripes and spots. An arboreal cat with great climbing skills (Mohamed et al. 2009; Sunquist and Sunquist 2017), it is little studied (Sanderson and Watson 2011; Sunquist and Sunquist 2014). The marbled cat is slightly larger and more slender than a domestic cat (Blanford 1888–1891), with a long and bushy tail that is similar in length to the cat's body. Their sides and back are prominently smudged with irregular, large and dark-fringed markings. Black dots are embellished on legs and underparts and the tail has proximal black spots and distal rings (Sunquist and Sunquist 2017). Out of the two distinct subspecies of marbled cats, *Pardofelis marmorata marmorata* and *Pardofelis marmorata charltonii* (ITIS 2018; Kitchener et al. 2017), the latter is distributed from the foothills of Nepal, through Sikkim, Assam and into upper Myanmar (Pocock 1939). *Pardofelis marmorata charltonii* has a much thicker and longer coat than *P. m. marmorata*, with a rich ochrous-brown colour (Pocock 1939).

The forest-dependent marbled cat is distributed throughout Southeast Asia, from the Himalayan foothills of India and Bhutan to China and then southwards through to Malaysia and Indonesia. The marbled cat has been recorded in Bangladesh (Hance 2016; Khan 2015), Bhutan (Tempa et al. 2013), Brunei Darussalam (Ross et al. 2016), Cambodia (Gray et al. 2014), China (KFBG 2015; Wang and Wang 1986), India (Choudhury 1996), Indonesia (Cheyne and Macdonald 2010), Lao People's Democratic Republic (Johnson et al. 2009), Malaysia (Azlan and Sharma 2006), Myanmar (Zaw et al. 2014), Thailand (Grassman et al. 2005) and Vietnam (Nowell and Jackson 1996). Although Nepal is noted as the westernmost end of the range in distribution for the marbled cat by the IUCN Red List (Ross et al. 2016), there has been no record of direct sighting or photographic proof of the species in Nepal (Dahal and Dahal 2017).

The distribution map for the marbled cat in Nowell and Jackson (1996) shows Nepal's Nawalpur, west of Chitwan National Park, as the westernmost record of the species based on a single dead specimen record of the species (Ross et al. 2016). However, the species was not recorded inside the park at that time. The nearest confirmed record

to Nepal is from Khangchengdzonga Biosphere Reserve in Sikkim, India and further south in the Manas National Park, in Assam, India. Despite many extensive camera-trapping surveys in Chitwan National Park and other parts of Nepal, there have been no records of the live marbled cat (Dahal and Dahal 2017; Lamichhane et al. 2014; Lamichhane et al. 2016; Yadav et al. 2018). One skin of the species was collected by B. H. Hodgson and presented to the British Museum and labelled as 'Nepal' (Pocock 1939). It is assumed that the skin might have been collected during his studies between 1823 and 1843. Blanford (1888–1891) reported the marbled cat as present in Sikkim but not in Nepal. Similarly, a mammal survey report in Nepal by the Bombay Natural History Society found no evidence of the marbled cat in Nepal and speculated that Sikkim may have been the origin of the Hodgson's specimen (Hinton and Fry 1923). Pocock (1939) declared the claim of Blanford (1888–1891) to be wrong without presenting any reasons. Horsfield (1856) only mentioned 'hilly region' not the area as the habitat of marbled cat in his catalogue of the collection of Mammalia from Nepal, Sikkim and Tibet. Pocock (1939) also mentioned that the species was very hard to obtain for collection and seldom received alive by zoos. At that time, the team members of the Bombay Mammal Survey were not able to capture or buy a single animal from the indigenous people in Nepal, Sikkim, Assam and Myanmar. This also indicates the naturally potential rarity of the cat at that time.

The species is primarily found in moist and mixed deciduous-evergreen tropical forest and prefers hilly forests (Duckworth et al. 1999; Grassman et al. 2005; Holden 2001; Nowell and Jackson 1996). The marbled cat is also found in secondary and logged forests, clearings, mangroves and on the periphery of the oil palm plantations (Bernard et al. 2013; Hearn et al. 2016; Ross et al. 2010). The marbled cat's diet likely consists of squirrels and rats and birds, up to the size of pheasants (Nowell and Jackson 1996; Pocock 1932). This matches what is known from an individual in captivity (Sunquist and Sunquist 2017). Additionally, there is a report of the hunting of a juvenile male Phayre's leaf monkey by a marbled cat in Thailand (Borries et al. 2014).

The species occurs in isolated and fragmented habitat patches in some part of their distribution range (Ross et al. 2016). The loss of the habitat caused by deforestation is considered as a major threat for the species. Indiscriminate snaring is also common throughout much of its range and is likely a threat to the species (Ross et al. 2016). Body parts of this species were also reported from an illegal market of Yunan, China (Haibin and Kunming 1999). The marbled cat is also hunted for meat (Selvan et al. 2013a) and for socio-cultural rituals by some tribal groups in India (Selvan et al. 2013b). Amongst the numerous confiscations of leopard pelts, there is no record of marbled cat pelts in Nepal (CIB 2018).

Camera traps have been recording and providing new information on distribution and aspects of ecology, in recent times, of small and medium-sized wild felids throughout Southeast Asia, such as the marbled cat (Tempa et al. 2013; Thinley et al. 2015; Wibisono and McCarthy 2010). Camera traps provide absolute evidence that a species is present in an area but are not sufficient to propose conservation action without associating natural densities, habitat quality, quantity, connectivity, land use, hunting pressure etc.

The first ever camera trap photograph of a marbled cat was captured during daylight hours in Huai Kha Khaeng Wildlife Sanctuary in Thailand in 1994 (K. Conforti. pers. comm. as cited in Nowell and Jackson 1996). Similarly, the first photograph of a marbled cat in the wild was taken in Khao Yai Wildlife Sanctuary, Thailand in 1993 (Jackson 1997).

Some areas of Panchthar district (Nepal) are also connected to the protected areas of Sikkim (India) and the habitat area is similar to the habitat in Sikkim, where the occurrence of marbled cat was reported by Balnford (1888–1891). The habitat area in Nepal has much pressure from the anthropogenic activities like free-range cattle grazing, fuel wood and fodder collection.

Methodology

A camera-trapping study was conducted in non-protected forest areas of the Kangchenjunga landscape, bordering India on the eastern side, connecting the Singhalila National Park, Barsey Rhododendron Sanctuary and Khangchendzonga Biosphere Reserve, in far eastern Nepal (26°59'6.159"–27°25'57.969" N and 87°51'24.084"–88°6'34.282" E) (Figure 1). The elevation range of the study area lies between 2,000 to 4,355 m above sea level (m a.s.l.), covering about 520 km^2. The study area has been proposed as a conservation corridor to connect Nepal's Kangchenjunga Conservation Area (KCA) to these Indian conservation areas (Chettri et al. 2007). Monsoonal rain decreases from the beginning of October and the colder days increase in frequency, with the leaves of the deciduous hardwoods starting to fall by the end of November. This study area has been identified as a last remaining tract of Eastern Himalayan broadleaf forest, a major habitat for the endangered red panda (Williams 2003).

Dominant forest species and the composition of forest species changes with elevation, for instance *Quercus* sp. in lower temperate forest (1700–2400 m a.s.l.), *Quercus* sp., *Rhododendron* sp., and *Acer* sp., *Pinus* sp. in upper temperate forest (2400–2800 m a.s.l.), *Rhododendron* sp., *Betula* sp. and *Acer* sp. in subalpine forest (around 3000 m a.s.l.) and shrubby rhododendron species and junipers in the alpine zone (Dombremez 1976, as cited in Jackson 1994). Free range grazing has been in practice in the region for more than 170 years (Hooker 1889), is prevalent above 2,500 m a.s.l., impacting the forest area with over-grazing and has been listed as a major threat for biodiversity conservation (Shrestha et al. 2008).

A camera trap study was conducted to inventory the medium- to large-sized mammalian fauna in the region between December 2017 and June 2018, encompassing two seasons; winter (December 2017–February 2018) and spring (March-June 2018). The whole study area (Figure 1) was considered as a single block. The area above 2,000 m altitude was first selected by geoprocessing in ArcGIS 10.2. Then, we imposed uniform grid cells of 2 km × 2 km throughout the selected area. This resulted in 211 grids, of which 60 grids were sampled based on habitat type and accessibility. During field sampling, we omitted private forest areas and difficult rocky mountain

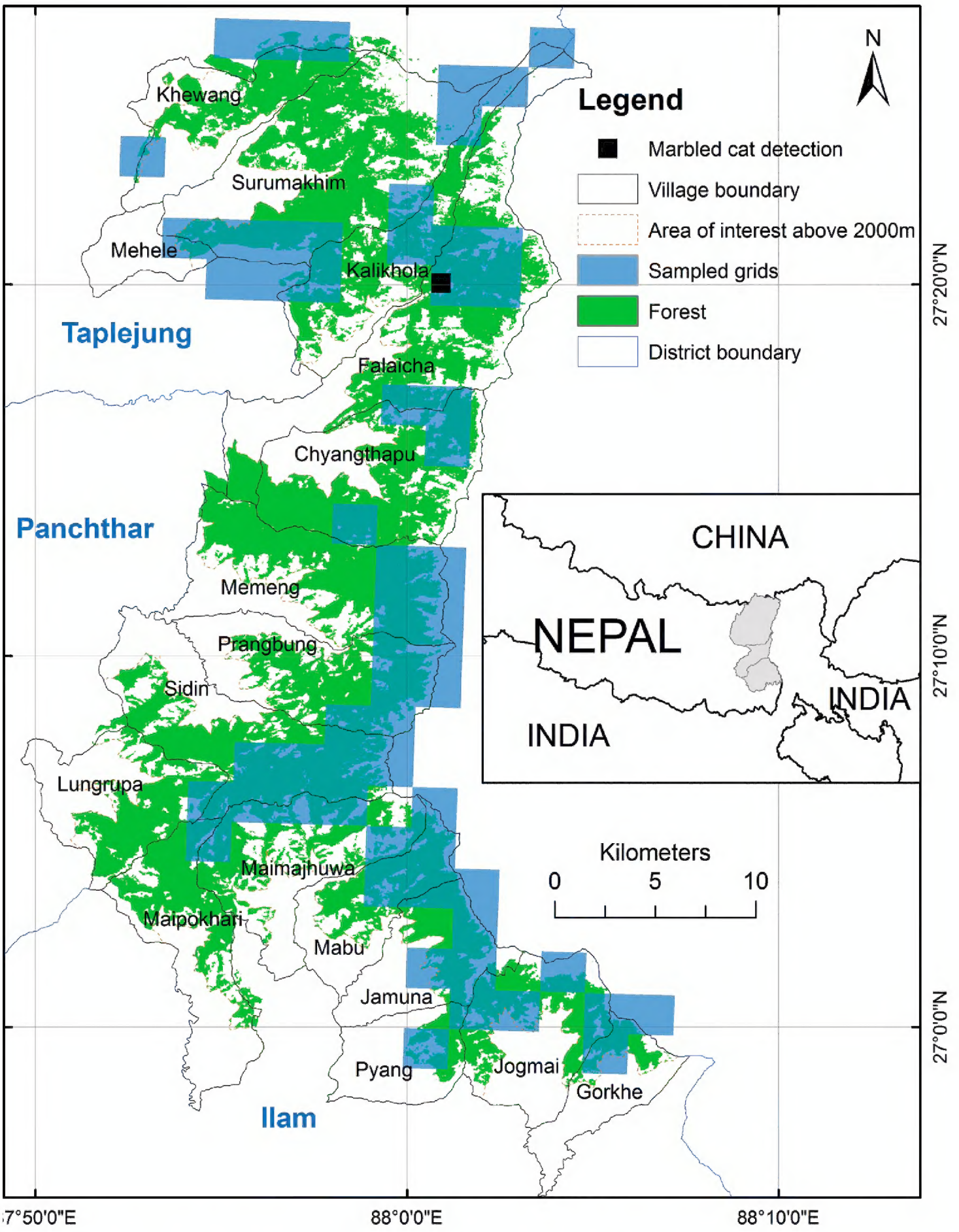

Figure 1. A map of the study area in Southern Kangchenjunga Landscape in eastern Nepal showing sampled grids in blue and location of the marbled cat detection.

cliffs and steep-mountain slopes because of inaccessibility. Within a selected grid, active trails and major areas of interest to wildlife, containing water sources, denning areas, major passes along mountain ridges and mineral licks, were chosen for the installation site of the camera traps.

We used 63 passive infrared camera trap units (51 Bushnell TROPHY Cam HD camera trap units from Bushnell Outdoor Products, USA and 12 units of Strike Force Elite camera traps, Model BTC-5HDE from Browning, Australia). The location and altitude of each site were recorded using a Garmin eTrex 10 and Rino120 handheld GPS.

On average, the cameras were left in the forests for 28 trap days. The minimum trap days for a camera was 14 days while 78 days was the maximum. The camera traps were installed at 107 locations. Cameras were secured to available tree trunks. The sensor height of the cameras installed above ground level was 32 cm on average. Every 24 hours was considered as one camera trap day for this study. The photographs were sorted manually and also with the help of Microsoft Access-based Camera Base 1.7 (Tobler 2015). The species from the photographs were identified with the help of the references from Sanderson and Watson (2011), Johnsingh and Manjrekar (2012) and Menon (2014), as well as consultation with experts and Forest Guardians from local villages who assisted with installing the camera traps. Photographs that were taken more than 30 minutes apart from each other were considered as independent events (Di Bitetti et al. 2006; Silver et al. 2004).

Results and discussions

Overall, there were 3,014 trap days (1,402 in winter and 1,612 in spring) from the 107 camera stations (52 in winter and 55 in spring) that collected 5,176 photographs of 17 medium-large sized mammal species. Of interest were three photos of a small felid (two whole body and one tail-only photo from its right flank) in a single event from a location ID W33 (27°20'2.22"N, 88°0'55.08"E; datum WGS84), (elevation: 2,750 m a.s.l.; aspect: west; slope: steep, details on Table 1) an dusk at 17:44 hr on 21 January 2018 (Figure 2). During the successive spring season (March-June), we surveyed the area where the marbled cat was detected intensively and systematically with seven monitoring stations. This resulted in 233 more camera days but with no more images of the marbled cat. One of the cameras was installed in previously trapped locations for a further 35 days.

The cat recorded location was near Tham Chok (a temporary shed for *dokpa*) from Phalaicha village in Panchthar District. The photos of the small felid were markedly different from other small cat images captured by other cameras in the area. A long, fluffy and erect tail, black edged large blotches on a flank and solid spots on the limbs were consistent with a marbled cat (confirmed by Igor Khorozyan, Jim Sanderson, Karan Shah, Kashmira Kakati, Rinjan Shrestha and Yadav Ghimirey). The camera trap images also matched (Figure 2) with published photos of the species (Dhendup et al. 2016; Nowell and Jackson 1996; Sethy et al. 2017). The marbled cat images clearly differed from the other felid species observed in this study, i.e. Asiatic golden cat, common leopard and leopard cat. The confirmation of the presence of the marbled cat at this site supports C. MacDougal's suggestion (Nowell and Jackson 1996) about the presence of the marbled cat in Nepal despite the lack of clear evidence about the origin of the cat's skin.

Table 1. Camera trap location details where the marbled cat was photographed in Southern Kangchenjunga region, eastern Nepal.

Parameter	Value
Location ID/Name of Location	W33/Tham Chok
Long/Lat	27°20'2.22"N, 88°0'55.08"E
Elevation	2,750 m
Total number of photos	3
No. of Independent events	1
Duration of camera placement	7–22 Jan 2018 (15 days)
Date, time & temperature of marbled cat recorded photo	21-01-2018, 17h 44m & 5°C
Habitat type	Upper-temperate mixed-broadleaved forest
Site aspect	West
Slope	Steep
Camera sensor height from ground	50 cm
Distance to nearest human settlement	1.4 km
Distance to nearest cattle herding station	0.4 km
Distance to forest edge	320 m
Distance to permanent water source	1 km
Distance to nearest forest in Sikkim, India	4 km
Distance to nearest trail for human & livestock	50 m
Other mammal species captured at the same camera	Orange-bellied Himalayan squirrel & Northern red muntjac
Bird species captured in the same camera	Kalij-pheasant
Species captured by the camera trap in same location in spring season	Leopard cat, Red muntjac, Yellow-throated marten and Wild boar

The habitat of the Tham Chok area is upper-temperate broadleaved forest (Figure 3). The vegetation in the area is dominated by *Lithocarpus pachyphylla*, *Castanopsis hysterix*, *Rhododendron grande*, *Taxus wallichiana*, *Lyonia ovalifolia* and *Alnus nepalensis* with thickets of *Arundinaria* sp. The recorded site is close to the Iwaa River, which originates from Timbung Lake at 4,200 m a.s.l.. The ridge is just above the confluence of Iwaa and Barne Rivers, which stretch towards the border with India, approximately 4 kilometres (km) away. The area is a summer grazing pasture for cows and goats and also a winter grazing pasture for dzomu (domestic yak-cow hybrids), supporting around 150 livestock over the winter. The eastern part of the Tham Chok is a largely rocky area with dwarf trees, probably recovering from a historical forest fire. A large area of primary forest in the Iwaa valley was burnt by a forest fire, presumably caused by incidental poachers, approximately 3.5 decades ago (pers. comm. K. Bhandari 2018). That forest fire caused huge damage to the local fauna and flora at that time. The habitat area is crisscrossed by human and livestock trails. A human trail was 50 m away from the camera trap station that recorded the marbled cat. The elevation record of the species in this study at 2,750 m a.s.l. is higher than the elevation limit of the species for Nepal (< 2,500 m a.s.l.) presented by Baral and Shah (2008). Despite a heavy presence of humans and livestock in the area, there is some pristine primary forest dominated by *Lithocarpus pachyphylla*, *Castanopsis hysterix*, and *Rhododendron* sp., in

Figure 2. An image of the first marbled cat in Nepal from the camera trap (Sonam Tashi Lama-Lincoln University/Red Panda Network).

the eastern portion of the area, approximately 2.5 km away. That primary forest could be a refuge habitat for many wildlife species, including small and medium-sized felids.

The other mammal and bird species captured at the same camera trap were the northern red muntjac *Muntiacus vaginalis*, orange-bellied Himalayan squirrel *Dremomys lokriah* and the Kalij pheasant *Lophura leucomelanos.* Similarly, leopard cat, yellow-throated marten *Martes flavigula* and wild boar *Sus scrofa* were recorded in the spring season. The photo-capture rate for that camera was highest for the muntjac followed by the squirrel in winter. The main prey present in the area, the orange-bellied squirrels (Figure 4) (Nowell and Jackson 1996) were also found to be strongly diurnal of habit in this study. Our images also support that marbled cat was primarily diurnal in their habit (Figure 2) as many other records around the world. A nearby camera trap, approximately 1 km away, only captured the photographs of dzomus, indicating the pressure of livestock in the area.

Marbled cat appear to have a very low capture rate throughout their range. The reason behind the low rate of the capture of the species could be due to the rareness of the species itself (Nowell and Jackson 1996; Azlan and Sharma 2006; Cheyne and Macdonald 2010). Failure to record the marbled cat during the spring season, despite intensive sampling of locations, may also indicate the rareness of the species in our study area or that we missed them because all of our cameras were based on the

Figure 3. The landscape and forests of the marbled cat capture area in Iwaa valley. The cat was photographed at far right (marked with red oval). (Sonam Tashi Lama-Lincoln University/Red Panda Network).

ground and they can be arboreal in nature (Sunquist and Sunquist 2017). Azlan and Sharma (2006) also reported a very low abundance of marbled cat (only one photo) and suggested that the cat could be rare and/or are mostly arboreal. Cheyne and Macdonald (2010), in Sabangau peat-swamp forest, Indonesian Borneo, did succeed in trapping a single image of this cat over 15 months, which further suggests the rarity of this species in the natural habitat. Camera-trap images of the marbled cat and the leopard cat were shown to nine *dokpa* in the first week of October 2018 and asked if they had sighted the cat in their area. Four of *dokpa* reported sighting the marbled cat, but all of them named it as a *chari bagh* (leopard cat). They understood them as a poultry pest that sometimes preys on goats. They had knowledge of the use of marbled cat skin and bones.

In a study by Hearn et al. (2016), the marbled cat was recorded from selectively logged area to primary forests but was not recorded inside the plantation forest. Their study estimated the density of the cat as higher than the Sunda clouded leopard *Neofolis diardi* and quite similar to the estimate of the leopard cat. In our study, the record of the leopard cat was relatively high.

The records of a marbled cat skull by Pocock (1939) from adjoining Darjeeling, India and one skin record originating from Sikkim, indicate that the cats were present in the region decades ago. This was also supported by the recent camera-trapped marbled

Figure 4. The Orange-bellied Himalayan squirrel *Dremomys lokriah*, a probable primary prey of marbled cat, is abundant in the study area. This individual was captured by the same camera trap (Sonam Tashi Lama-Lincoln University/Red Panda Network).

cat in Sikkim, adjoining and contiguous to our study area (pers. comm. P. S. Ghose 2018). This is consistent with the specimen collected by Hodgson from Nepal and the listing this species in the Nepal list by Horsfield (1856).

Hodgson was not allowed to travel outside of Kathmandu Valley during his stay in Nepal but he recruited a team of hunters and trappers to collect specimens for him (Datta and Inskipp 2004). He also did the same during his time (1845–1858) in Darjeeling, India (Hunter 1896) and his four assistants (bird and animal shooters, collector and taxidermist) travelled to eastern Nepal from October through to December 1848 with Sir Josheph Dalton Hooker (Hooker 1889). Due to the requests from the Lamas of Buddhists monasteries not to shoot or even fish in their surroundings (Hunter 1896), this might have limited the collection. On the other hand, some local ethnic people in eastern Nepal worked as licensed hunters for four generations to British India to hunt and trap birds and mammals for collections (pers. comm. S. B. Rai 2017).

The forest area, where the marbled cat was detected, has been naturally restored as a secondary forest after a forest fire that occurred nearly 3.5 decades ago. The slash-and-burn agriculture system was practised in the adjoining areas for many years until around 1998 (pers. comm. K. Bhandari 2018). The ongoing restoration of the secondary forests supports healthy biodiversity, including the top predators and provides

opportunities for combining forest regeneration and sustainable rural livelihoods for local people (Chazdon 2008). After banning grazing in the forest and removing mobile pastoralism in Sikkim in 1998 and Singhalila in 1992, the pressure of livestock has concentrated into the study area (Thomas 2014). The current number of livestock (cow, buffalo, yak, sheep and goat) in surrounding villages (Phalaicha and Kalikhola only) is 6,472 (MoLD 2017), of which at least 50% of them are grazing freely in nearby forests.

Small cats have been little studied in Nepal (Thapa 2014). The conflict between humans and marbled cat throughout its range appears to be low (Inskipp and Zimmermann 2009). It is not clear whether the low level of knowledge about the marbled cat throughout its range is due to rarity or its solitary and cryptic nature as a species (Sunquist and Sunquist 2017). In this context of limited knowledge on its ecology, distribution and status on a global level (Ross et al. 2016), we stress further research for gathering baseline data and appeal for conservation programmes outside the protected areas of Nepal. We expect to find the presence of the marbled cat in KCA, Makalu Barun National Park and most of the forested areas in the mid-hills of Nepal as the habitat and climates are similar to where we photographed the cat in eastern Nepal. As the coverage of forested areas by a camera-trapping survey in western Nepal is very low and limited to the protected areas, we cannot definitively conclude its absence from that region.

Based on a single presence location recorded in this study, it would be impractical to conclude anything about habitat characteristics for the marbled cat in Nepal. Limited information on population ecology, interactions with other sympatric felids, as well as how the species responds with the growing anthropogenic interactions in human-dominated landscapes, does not allow for an effective conservation plan. Nevertheless, the record of this species within a human-dominated landscape underpins the need for wildlife-friendly conservation measures to secure human-wildlife coexistence. Potential habitat identification following habitat zonation measures will help limit human activities outside the core habitat thus minimising the threat to some extent. However, an in-depth study on habitat characteristics, diet, distribution, movement and activity pattern will further guide in formulating an effective conservation plan targeting this species.

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